Introduction to the CDEX experiment

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It is believed that weakly interacting massive particles (WIMPs) are candidates for dark matter (DM) in our universe which come from outer space and might interact with the standard model (SM) matter of our detectors on the earth. Many collaborations in the world are carrying out various experiments to directly detect DM particles. China Jinping underground Laboratory (CJPL) is the deepest underground laboratory in the world and provides a very promising environment for DM search. China Dark matter EXperiment (CDEX) is going to directly detect the WIMP flux with high sensitivity in the low WIMP-mass region. Both CJPL and CDEX have achieved a remarkable progress in recent three years. CDEX employs a point-contact germanium (PCGe) semi-conductor detector whose energy threshold is less than 300 eV. In this report we present the measurement results of muon flux, monitoring of radioactivity and radon concentration carried out in CJPL, as well describing the structure and performance of the 1 kg-PCGe detector in CDEX-1 and 10 kg-PCGe detector array in CDEX-10 including the detectors, electronics, shielding and cooling systems. Finally we discuss the physics goals of CDEX-1, CDEX-10 and the future CDEX-1T experiments.

Keywords China Dark matter EXperiment (CDEX), dark matter, point-contact germanium detector, China Jinping underground Laboratory (CJPL)

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1 Introduction

Observation of the existence of dark matter (DM) undoubtedly was one of the greatest scientific events of the 20th century, then directly searching for DM and identifying it will be the most important and challengeable task of this century.

As a matter of fact, the conjecture about the existence of DM was proposed quite a long time ago in 1933 by Zwicky [1] stating that near the Coma cluster of galaxies velocity distribution implies more cluster mass than luminous matter and then in 1970 and later Rubin [2–4] reported the anomalously rotation curves of galaxies. The astronomical observation shows that the rotational curves of the test galaxies did not obey the gravitational law if only the luminous matter which resided at the center of the cluster existed. Namely, the velocities of test galaxies were supposed to be inversely proportional to the square roots of their distances from the center of the cluster, but instead, the rotational curve turns flat. It implies that there must be some unseen matter in the galaxy, i.e., DM. Moreover, hints about the existence of DM also appear when a collision of two clusters of galaxies was observed [5]. It was observed that for each cluster, the center of mass does not coincide with the center of the luminous matter after a collision between two clusters. It is explained as that two clusters both of which are composed of DM and luminous matter, collide, and after collision, the dark components penetrate through each other because they do not participate in electromagnetic interaction (EM) nor strong interaction, but the luminous fractions of the two clusters interact with each other via EM interaction, so remain near the collision region while the dark parts have left.

Moreover, all astronomical observations indicate that our universe is approximately flat [6], i.e., the total \( \Omega \) defined as \( \rho/\rho_c \) where \( \rho_c \) is the critical density and \( \rho \) is the total matter density in our universe, is close to unity. However, the cosmic microwave background (CMB) and big bang nucleosynthesis (BBN) data show that the fraction of luminous baryonic matter density \( \Omega_b \) is less than 5% and over 95% of our universe is dark. Further analysis [7] indicates that DM may take a fraction of 26.7% while dark energy occupies the rest over 68.3%. The dark energy is the most mysterious subject for which so far our understanding about the universe is not enough to give a reasonable answer even though there are many plausible models. By contrary, DM may have a particle correspondence.

The commonly accepted point of view [8] is that the main fraction of DM in our universe is the cold dark matter (CDM), which could be weakly interacting massive